Indoor MMS and Digital Twin to get the spatial data of a large real estate asset

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Key words: indoor mobile mapping, Digital Twin, LiDAR, laser scanner, virtual tour

SUMMARY

The acquisition of building assets is increasingly becoming an indispensable activity for a modern and efficient management of large real estate assets. It can be said that more than 90% of surveying activities are currently involving geospatial applications. These activities can be carried out with great productivity with indoor mobile mapping systems, if appropriate equipment is used and if the information, data acquisition and processing workflow are organized with great care. The article presents these issues and how have been solved, by introducing the case of a success story or the geospatial survey of almost 500 buildings required by an engineering company Metropolitana Milanese in the municipality of Milan in North Italy.

SOMMARIO

Le attività di acquisizione degli assets di edifici stanno diventando sempre più una attività indispensabile per una moderna ed efficiente gestione di grandi patrimoni immobiliari. Si può affermare che più del 90% delle attività di rilevamento riguardano al momento applicazioni geospaziali. Tali attività possono essere con grande produttività realizzate con sistemi di indoor mobile mapping, a patto che si usi una strumentazione opportuna e che il workflow di acquisizione e trattamento delle informazioni e dei dati sia organizzato con grande attenzione. L'articolo presenta queste problematiche introducendo il caso di una storia di successo ovvero del rilevamento di circa 500 edifici appaltato dalla società di ingegneria Metropolitana Milanese nel comune di Milano in Italia del Nord.

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1. INTRODUCTION

The acquisition of building assets is increasingly becoming an indispensable activity for the modern and efficient management of large real estate assets. It can be said that more than 90% of surveying activities currently concern geospatial applications. In this sense, detection methods are now consolidated using tablet tools that allow an operator to map and survey the assets of a building, simply by walking through it and marking the position in correspondence with a map of the previously surveyed and/or projected building . These systems, certainly effective, are now being replaced more and more widely by mobile BIM solutions or by software dedicated to the world of Construction and Facility Management. These solutions are usually based on a photographic acquisition that allows the information and assets recognized in the field to be associated with an existing BIM model and which implement augmented reality algorithms (Bae, 2013) (Qiuchen, 2020). These applications are being effectively supported by solutions that involve the use of systems that are not limited to two-dimensional photographic acquisition, but implement 3D detection technologies based on indoor mobile mapping, static laser scanner scans and digital photogrammetry. These technologies, combined or used in isolation depending on the case, make it possible to operate effectively even in environments where the geometries and the 3D model are not known and even more so there is no existing BIM model. On the contrary, these technologies, in addition to allowing the detection of the assets of a building and the relative placement in space, also allow to obtain and extract the BIM model, at the desired LoD (Level Of Development). So here we are moving towards the concept of Digital Twin, i.e. an object inside which the 3D spatial and information components of a BIM are added, the data and information coming from a network of sensors and in which advanced recognition processes of assets allow you to compose an intelligent model, updatable and full of dynamic information of the surveyed building (Qi, 2018) (Khajavi, 2019). In particular, while BIM models are useful tools for building management in its construction phases and for collaboration between stakeholders, the Digital Twin of a building is implemented to organize the maintenance activities, to reduce maintenance costs and to record in the time the building maintenance history (Cantoni et al. 2019).
Indoor Mobile Mapping approach has become a very useful tool to support Digital Twin projects. The use of mobile mapping systems based on active LiDAR sensors synchronized with high-resolution photographic cameras, has become of common use also thanks to the fast and significant development that this approach had in the recent months. These instruments represent an interesting solution for the spatial acquisition of buildings and the simultaneous acquisition of high-resolution RGB panoramic images of large sites.

2. THE SUCCESS CASE

The success case introduced in this paper, presents the use of mobile mapping, and in particular the use of a SLAM based mobile mapping system to realize a large assets survey of almost 500 social housing buildings located in Milan, North Italy (Figure 1). The buildings are part of a real estate owned by the municipality of Milan and managed by Metropolitana Milanese (MM) (an engineering company). The main request of MM, that has the task to carry on the maintenance of these buildings, is to get all the geospatial information needed to reduce the maintenance costs. In the same time a fast mapping of all the sites was required, due to the fact the very few geometric information (maps, prospects, etc..) are known about this large number of buildings. For this reason, to realize the data acquisition, it was decided to use a technology that would allow both the geometric survey of the buildings, and acquisition of the buildings' assets through photographic support composed of panoramic RGB photographs.
The 3D survey is also needed to recognize how the sites are organized, in order to uniquely identify where the assets are located, for example at which level, along the stairs or in a common room, inside a technical room or in the parking site. The mapping activity was limited to the area of use by all the building community and not inside the family apartments.

Figure 1: The common organization of the buildings, part of the mapping project

3. PAPER'S GOAL

The main goal of the paper is to describe several details that have to be considered when using mobile mapping technologies for geospatial projects applied to large real estate mapping. Surveyor have often several concerns about the real, and proven accuracy of the SLAM based mobile mapping systems. This concern is correct, due to the approach that these devices use to define the trajectory that, can be said, is not independent to the geometry of the mapped sites. In this case, the goal of the project, wasn't to extract a correct model of the buildings at cm level. A global accuracy of 20 cm was admitted and few centimeters of accuracy at local level (we could say at scan level) tolerated. The main issue of the project was to correctly get the biggest amount of geospatial data located inside and on the external surroundings of the complex of building, at a sustainable time and cost. Several important issues have been identified and a correct approach described.

4. INDOOR MOBILE MAPPING

The choice was therefore directed towards the indoor mobile mapping technology (iMMS), which would allow the acquisition of a moderate quality 3D model of the sites but can assure a quality RGB information mapped on the model itself. In particular the three-dimensional model was needed to support 3D geometric measurements of the environments surveyed and to get a fast general view of the entire building complex.

Figure 2: An example of fast extraction of a 2,5D point cloud orthophoto of a complex of buildings

The high resolution photographic images, acquired together with the 3D survey, have the important role to allow the recognition of the objects present in the surveyed areas.
It is for this purpose that an iMMS system based on a SLAM algorithm has been chosen by MM, in order to operate both in indoor and outdoor environments, equipped with a high resolution photographic camera, having 3D mapping capabilities so to support the survey of large buildings sites.

4.1. The instrument used for mapping

The surveyor, winner of the public tender, has chosen as iMMS device the Heron MS Twin Color instrument (Figure 4), produced by Gexcel srl (Gexcel 2023). The instrument is characterized by a capture head with two LiDAR sensors; one having 16 channels and the second 32 channels (Marotta et al. 2022). The 32 channels sensor works horizontally and has a maximum measuring range of 200 meters, while the 16 channels one has an inclination of 45° respect to the other sensor and has a range of 100 meters. On the top of the capture head a 4 lenses digital camera is mounted. The camera is capable of acquiring 8K resolution RGB images, on demand, fully synchronized and geometrically calibrated in the point clouds acquired by the LiDAR sensors. The trajectory computation is based on the well-known SLAM technology, and the processing steps are described in (Marotta et al., 2022),. The main characteristics of the sensor of the instrument, installed on the capture head (Figure 3), are detailed in Table 1.

Sensors installed in the capture head	
Lidar sensors	
LiDAR sensor #1 *Model*	Velodyne ULTRA Puck VLP-32C
Channels	32
Point per seconds	1,200,000
Max laser range	200 meters
Field of View (FoV) (horizontal)	360° surround view
Field of View (FoV) (vertical)	+15 ° to - 25 °
Accuracy	3 cm
Minimum angular Resolution	0.33 vertical resolution (non-linear distribution)
Laser	Wavelength: ~903 nm – Class 1
LiDAR sensor #2 *model*	Velodyne Puck LITE
Channels	16
Point per seconds (Single return mode)	300,000
Point per seconds (Double return mode)	600,000
Max laser range	100 meters
Field of View (FoV) (horizontal)	360° surround view
Field of View (FoV) (vertical)	+15 ° to - 15 °
Accuracy	3 cm
Angular Resolution	0.1° – 0.4°
Laser	Wavelength: ~903 nm – Class 1
CAMERA *model*	Gexcel - MG1- Multi optical sensor
Resolution	8k on demand
IMU	
Model	Gexcel - MG1- Multi optical sensor
Resolution	8k on demand

Table 1: Datasheet of the sensors installed in the Heron iMMS capture head

The choice of the type of tool to use was dictated by some technical and operational evaluations. In fact, many instruments based on SLAM algorithm using active sensors as LiDAR, are currently available in the market; each instrument has some specific optimal applications where its own characteristics provide the best performances. There are several optimal instruments and each of them provide the best performance in one particular application field.

Figure 3: HERON iMMS: the capture head

Figure 4: The Heron MS Twin color used in the project (Courtesy of Gexcel srl)

5. WORK AND DATA ORGANIZATION

In this paper we are not going in the details of the main characteristics of every mobile mapping devices and about the accuracy that it is possible to obtain from this typology of instruments. A large number of paper have been written on this topic, carried out with numerous tests and numerous evaluation studies in this regard are available (Nocerino, 2017), (Marotta, 2022), (Otero, 2020). On the other hand we will analyze some problems that have to addressed and resolved in order to make the work effective and feasible in practice, which are often considered of minor importance but which represent the indispensable step to make these technologies truly usable.

5.1.Close trajectory loops

What makes the use of HERON of particular interest in this project, has been its particular characteristics in the post processing software (HERON Desktop software), where the instrument trajectory during the acquisition phase can also be a no closed loop, as required by several iMMS devices. SLAM algorithm, as is well known, estimates the operator's trajectory not thanks to the position of a GNSS sensor, but rather through an algorithm which, by observing the not moving reality that surrounds the moving operator, is able to compute its position or rather the trajectory. Many algorithms require, in order to optimize the trajectory calculation, that the trajectory in realized as a closed loop; the point where the operator starts the mobile measurements, have to be the same where the operator ends the acquisition. In the present case, this constraint could represent an important problem, in terms of timing of field work and also lengthening the data processing time. In fact, while for a building with a prevalent planimetric development, as for example inside an industrial plant and/or an urban environment, the loop closure of the trajectory is not a problem. For buildings of 6/10 floors, with mainly vertical development, such as for the buildings of the municipality of Milan; having to detect the stairs means doubling the mapping times, if the mapping instruments forced to start and finish from the same position.

5.2 Data organization

Regarding the organization of the data, it must be taken into consideration that the main objective of the survey is not the creation of a three-dimensional model of the buildings, but rather the creation of a census of all the assets located in the buildings. In our case, MM, already has the structure of the database of the information and assets they need to run the buildings maintenance. These are the characteristics of lighting points, the elevator, boilers, intercoms devices, and more than 100 hundreds assets.

The need is, in particular, the knowledge of the position of each detected element, not in terms of coordinates, but rather of annotation of the area in which the detected elements are located. For example, it is necessary to know which types of lighting point or electrical panel are placed at a certain level on the staircase of a specific building or the location of an electrical panel located on a particular room placed at the second floor of staircase C of building N of the complex M. It is therefore necessary to organize and subdivide the building or complex of buildings in the areas that composed them, and the data have to be structure according to the real organization of the areas in the buildings. This operation is usually delegated to the post-processing phase, in which the different detection elements are attributed to every specific different area of the building. However, this approach is extremely costly and time consuming, almost impossible to be done, in particular by the post processing staff that is usually different from the surveyors that manage the field work. It is necessary to develop some kind of tool or procedure, that for every part of the trajectory associated the name of the area where the data have been captured. It is in fact important that this information are acquired during the acquisition phase. This is possible to realized, if the surveyor is enabled to associate every element to the location, thanks to an appropriate software tool that speed up this tagging procedure. Table 2 shows the location structure developed to organize the data of the project, for every complex of buildings.

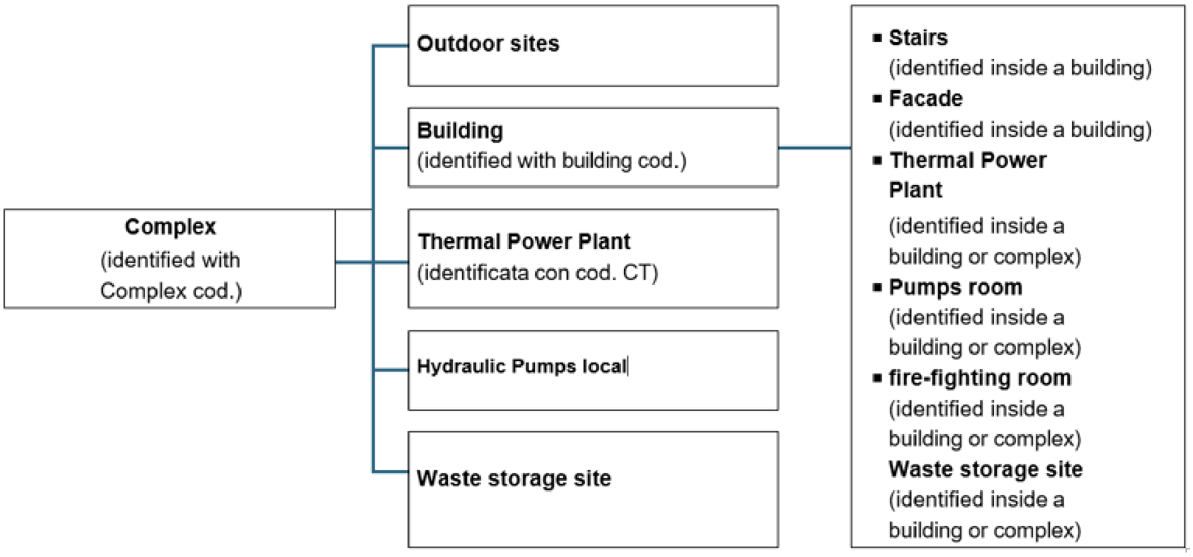

Table 2: The structure of the location for every complex of buildings

5.3 Cloud based virtual tour per il riconoscimento degli assets

In order to allow an effective recognition of the assets, a procedure has been proposed and applied that allows an operator of the main contractor (MM) to visually recognize the assets in the images acquired in the field. This procedure is organized so to share the 3D data and spherical images in a cloud based portal, creating a virtual tour inside the survey, using a Google Street View-style navigation. Due to the fact that the results of the 3D mapping survey by HERON is not a cloud based structured data but from a single 3D model, the data has been exported creating a virtual 3D scan in the position where the panoramic high resolution RGB pictures have been acquired. The data has been exported in E57 format and visualize in the cloud thanks to the Cintoo platform (Cintoo, 2023), capable to share the 3D data also starting from a spherical image visualization, having the 3D information on the background. As it is possible to observe in figure 5, the data are (left hand site) organized in a clear structure, so that the operator can easily recognize the position where the recognized assets are locate.

6. CONCLUSIONS

This success story, still in progress on march 2023, is an important example of how the innovative mapping tools have to develop smart tagging capabilities to satisfy the growing needs of the geospatial, having a great interest to synchronize the 3D mapping capabilities of instruments as indoor mobile mapping systems, with the data capture and recognition. The use of innovative on the field tagging tools, the implementation of machine learning algorithms and procedure, are still in progress and big efforts are required to the software and instruments developers and researchers on developing innovative tools to support this growing need of the geospatial market.

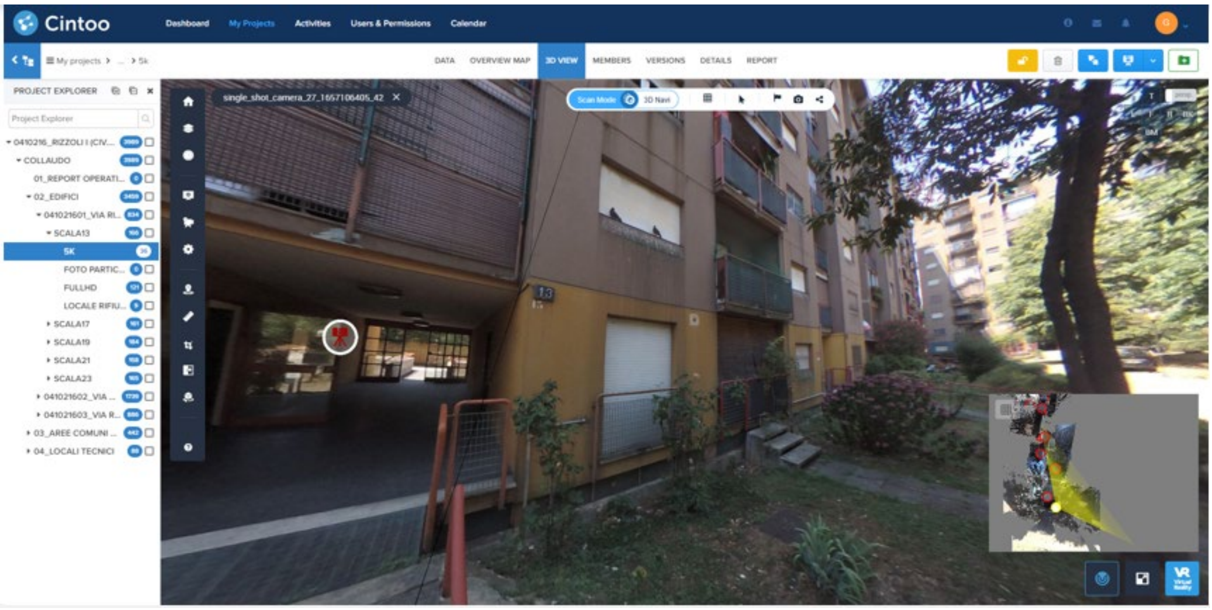

Figure 5: The data navigation in the Cintoo platform (Courtesy of Gexcel srl)

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BIOGRAPHICAL NOTES

Graduated in civil engineering at the Milan Polytechnic, he made his doctorate in geodetic sciences, in particular on Leaning Tower of Pisa and large construction sites deformation monitoring. He is currently responsible for the topography chair at the University of Brescia (Italy), Department of Civil, Environmental, Architectural Engineering and Mathematics (DICATAM). He is the founder of Gexcel srl, the first spin-off company of the University of Brescia, that produce the indoor mapping solution HERON partially described in this paper. He is involved in several research topics in particular: monitoring in construction and infrastructural sites, GNSS, mobile mapping technologies, LiDAR monitoring of glaciers and open pit mines, innovative technologies for tall structures mapping and deformation monitoring.

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